Document 9

PACIFIC SARDINE TRAWL SURVEYS – CANADA

Prepared for
WORKSHOP ON ENHANCING STOCK ASSESSMENTS OF PACIFIC SARDINE IN THE CALIFORNIA CURRENT THROUGH COOPERATIVE SURVEYS
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Jake Schweigert
Department of Fisheries and Oceans Canada
Nanaimo, B.C., Canada

I. Introduction and Background of Survey Method

Surveys of marine fish populations are generally undertaken to obtain estimates of absolute or relative abundance of the species of interest as well as obtaining data on their distribution and biological attributes (length, weight, sex, age, maturity, etc.). The general theory behind trawl survey sampling methods is that if one assumes that the population is randomly distributed within the area of the survey then it is reasonable to expect that conducting a number of trawl sets in the area will provide an unbiased estimate of the average density of the species in the area of interest and then the mean density can be expanded to the entire distribution of the species to estimate the total population size. However, there are a number of considerations that will impact the ability to conduct this survey in a manner that will provide an accurate (unbiased) estimate of population size.

Possibly the most difficult variable to assess is the total area of the population distribution. The ocean is pretty big and so it is not a simple task to cover the area of possible distribution and confirm that there are no additional schools outside the survey area. Missing schools will impact the estimate of total population abundance and result in an inaccurate estimate (biased low).

Another factor that affects the accuracy of trawl surveys is vessel and gear avoidance. In particular, sardine are surface oriented so that they will be easily disturbed by an approaching noisy vessel and move away from the trawl path, similarly larger fish may have a higher ability to avoid approaching nets. Again the result would be to underestimate sardine density (biased low).

Perhaps the most critical assumption in a trawl survey program is that the population is randomly distributed while we know that fish are generally in schools and that the schools are distributed in patches. As a result attempts to make ‘random’ sets within a survey area will provide a biased estimate of fish density. A huge statistical literature exists on determining the correct distribution of the population from trawl surveys and how to either transform the data prior to analysis or assume a different sampling

distribution for the data than the usual normal distribution. The effect of this assumption is really to alter the estimate of variability around the abundance estimate depending on sampling distribution that one assumes. It generally does not impact the estimate of average population density and total abundance.

The output of the trawl survey can be an estimate of the total population if there is good evidence that the entire distribution of the species of interest has been sampled or it can provide an index of population abundance that can be used to monitor trends in abundance and as such could feed directly in a stock assessment model such as a catch-age analysis.

The major advantage of the trawl survey is that it is empirical so that if one conducts enough trawl sets it is possible to determine whether the population is increasing, decreasing, or stable. The biggest disadvantage is that it is expensive and difficult to cover the entire distribution of sardine in a reasonable time frame. It also requires a lot staff to support the survey and analyse the data.

II. Design for Survey in the CA Current

Surveys employing mid-water trawls near the surface have been conducted on the west coast of Vancouver Island from 1992 to present to examine the distribution and relative abundance of sardines (McFarlane and MacDougall 2001). Abundance estimates were calculated using representative catches from the surface to 30 m depth, collected during surveys in late June, July and August. The July surveys have generally been most indicative of the relative sardine biomass in Canadian offshore waters. For estimating abundance, the west coast of Vancouver Island was partitioned into 6 major "regions" or sampling strata (Figure 1), 5 of which were sampled in most survey years. Sampling was considered complete when sampling occurred in Areas 2-6 whereas when regions were omitted due to time constraints (i.e. Areas 2 and 3), sampling was considered "incomplete" and not representative of distribution and abundance.

The total surface volume of each region was estimated using the maximum depth fished (30m).

Total surface volume (km^3) – Regional area (km^2) * 0.030 km.

Total volume for each region was determined by multiplying the area determined for each region by maximum net depth (30m, or .030km):

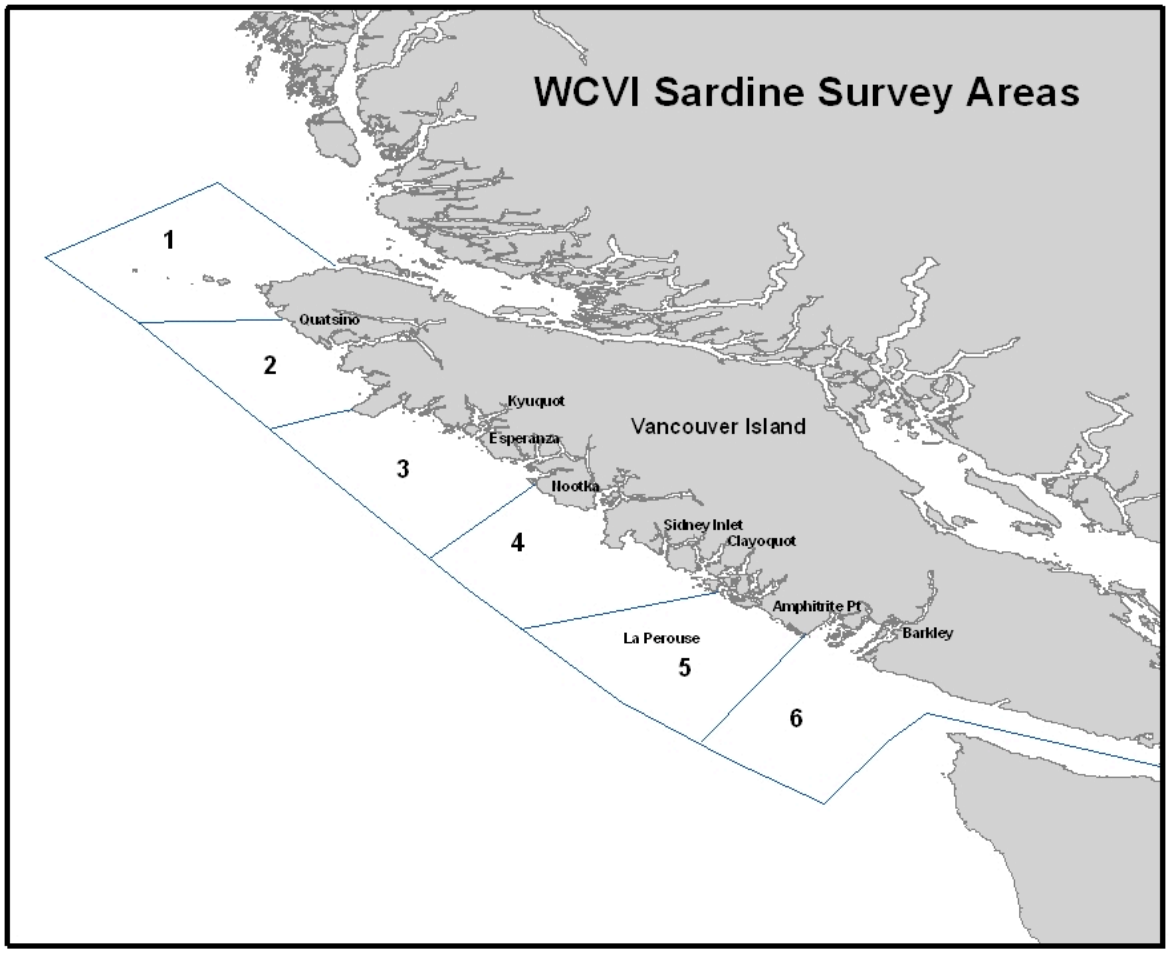
Total volume (km^3) = Area of region (km^2) * 0.030 km

Each region contained 3-5 transects with 2-51 tows or "sets" per transect. Transects were run parallel or perpendicular to the shore, depending on weather, tides and currents, out to a bottom depth of 500 m. Tows of 20-60 minutes duration were conducted sequentially along the length of each transect (i.e., constant fishing). The swept volume of each tow

was determined by multiplying the area of the opening of the trawl net by the distance travelled:

Swept Volume (km3) = Net height (km) * Net width (km) * Distance (km)

From each tow, total sardine catch was recorded by piece count or by weight. If sardine catch was only recorded by weight, the total number of fish caught was estimated by dividing weight (in kg) by the average individual sardine weight for that region. Using



estimates of swept volumes for tows from the same region, estimates of average swept volumes and 95% confidence intervals were calculated for each region.

Figure 1: Pacific sardine sampling strata off the west coast of Vancouver Island.

Day/ Night Calibration

From 1997 to 2004 all sets were conducted during daytime hours. In July 2005, day/night catch comparisons were conducted off Nootka Sound and Barkley Sound to estimate

day/night catch ratios. In these areas, all sets were completed during 2 days and 2 nights of fishing. In 2006 and 2008, all tows were conducted at night and the calibration factor from the 2005 day/night catch ratios was applied to results from these 2 years to represent daytime catches.

Abundance

Biomass estimates were calculated from data collected during cruises from 1997 to 2008 (Table 1). Biomass estimates were calculated according to the method described in Beamish *et al*. (2000) assuming a stratified random sampling design. For each regional stratum, total abundance was estimated as the number of sardines per swept volume times the total swept volume:

$$C_h = \frac{V_h}{\bar{v}_h} \bullet \bar{c}_h$$

where

h = regional stratum (Areas 2 to 6)
C_h = estimated number of sardines in stratum h
$\bar{c}_h$ = average number of sardines caught in stratum h
V_h = estimated surface volume of stratum h
$\bar{v}_h$ = average swept volume of all sets in stratum h
$N_h = V_h/\bar{v}_h$, or the total number of possible samples of size $\bar{v}_h$ in stratum h

The corresponding variance estimator for abundance in the h th stratum is:

$$\text{var}(C_h) = \sum_h N_h(N_h - n_h) \bullet \frac{S_{ch}^2}{n_h}$$

where catch sample variance by stratum is represented by:

$$S_{ch}^2 = \frac{\sum_i^{n_h} (c_{hi} - \bar{c}_h)^2}{(n_h - 1)}$$

c_{hi} = number of sardines caught in sample i in stratum h
c_h = average number of sardines caught in stratum h
n_h = number of samples taken in the h^{th} stratum

Abundance in number of sardines was converted to weight (kg) by multiplying abundance in numbers by average weight (kg) of an individual sardine by stratum:

$$B_h = \frac{V_h}{\bar{v}_h} \bullet \bar{c}_h \bullet \bar{w}_h$$

where

$\bar{w}_h$ = average sardine weight (kg) in stratum *h*

For 1997, 1999, and 2001, the average sardine weight in all strata was estimated as 0.165 kg because fish sizes were similar.

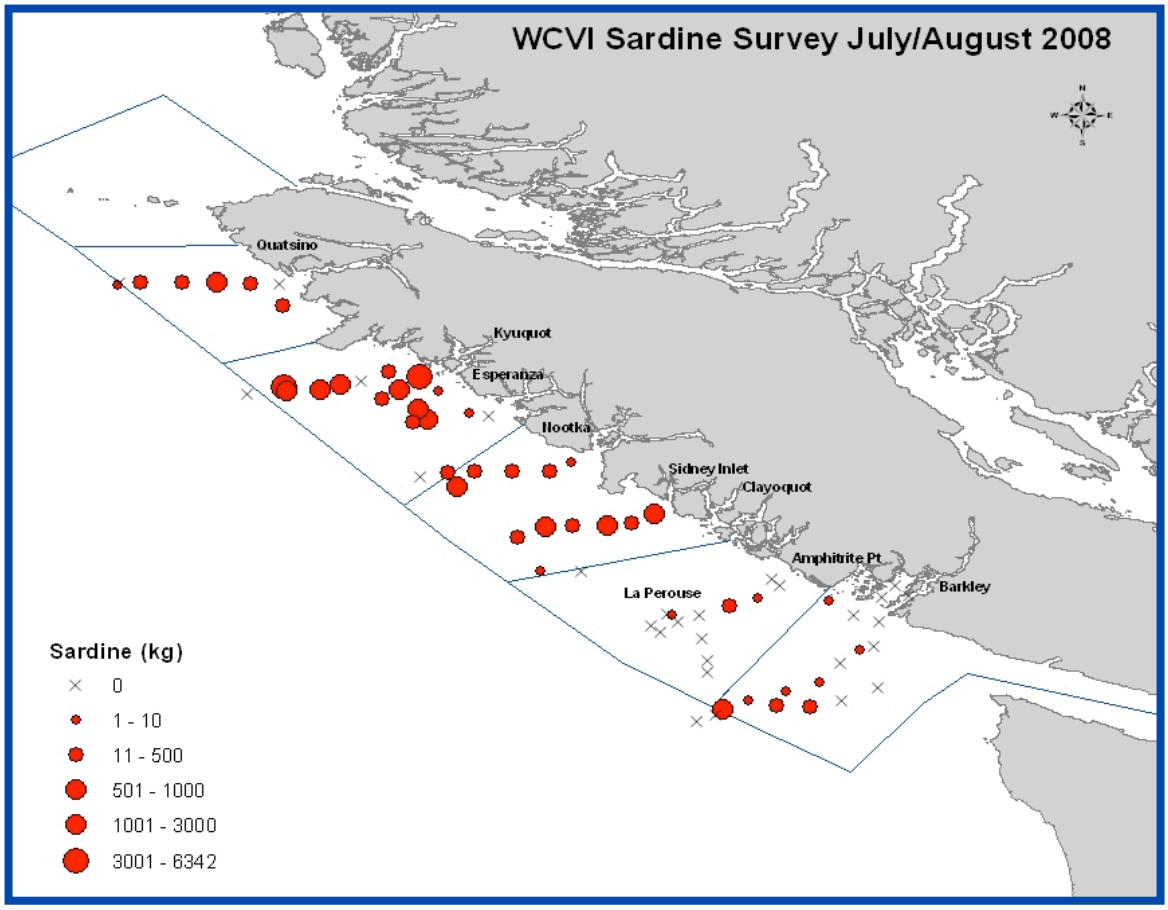
The corresponding variance estimator for abundance (weight) in the *h* th stratum is:

$$\text{var}(B_h) = \sum_h N_h (N_h - n_h) \bullet \frac{S_{bh}^2}{n_h}$$

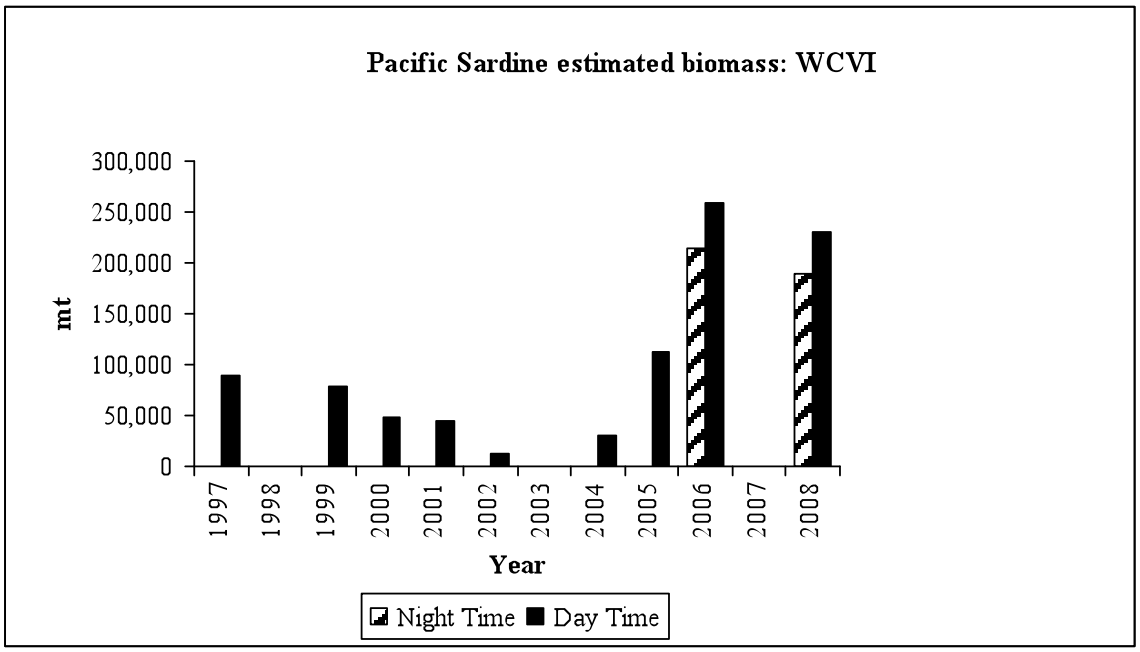
where catch sample (weight) variance by stratum is represented by:

$$S_{bh}^2 = \frac{\sum_i^{n_h} (\bar{w}_h \bullet c_h - \bar{w}_h \bullet \bar{c}_h)^2}{(n_h - 1)}$$

Minimum and maximum biomass estimates were determined using an approximate 95% confidence interval determined as the average biomass plus or minus twice the standard error (square root of the estimated sample weight variance).



Typical sampling coverage of the sardine trawl survey is shown above. In addition, we obtain anecdotal information on sardine distribution and relative abundance as bycatch in a high seas juvenile salmon survey that occurs 2-3 times annually.



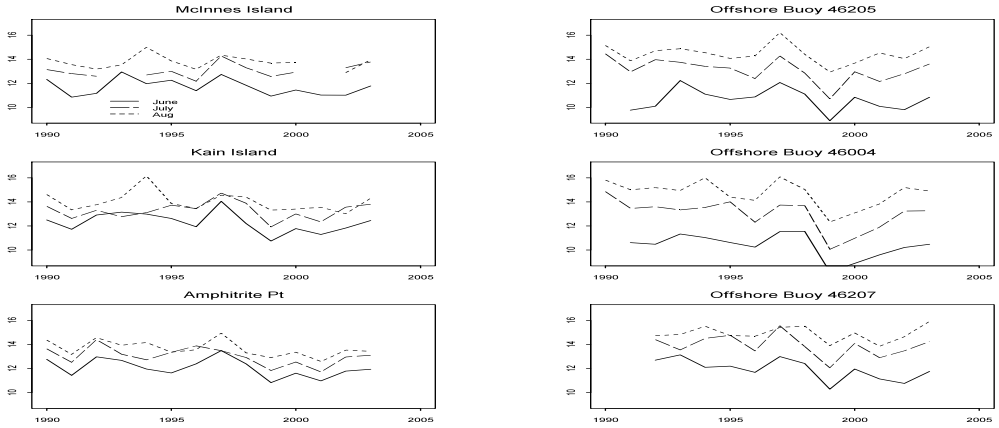
Estimated time series of sardine abundance off the west coast of Vancouver Island since 1997.

III. Lessons Learned from Application

In general, we have been relatively satisfied with the results and application of the trawl methodology in Canadian waters. The outstanding issue that remains is describing the northerly extent of the annual feeding migration. A considerable portion of the fishery occurs in areas north of Vancouver Island where we have not surveyed or sampled and yet an abundance of sardine is clearly present. The annual survey is constrained by availability of vessel survey days and since this is oversubscribed we have been constrained to focussing on the key strata along the west coast of Vancouver Island that have contained the bulk of the sardine in the past.

It appears that the northward movement of sardine is somewhat constrained by the location of the 12C isotherm and indications are that in some years (eg. 1999-2001) when oceanographic conditions were relatively cold offshore areas did not reach 12C until August whereas sardine generally appear off Amphitrite Point towards the southern section of Vancouver Island in late June. Additional analysis of available oceanographic data is needed to better understand the constraints and extent of the annual northward migration to better time the survey and modify the spatial coverage as necessary.

The major improvements to the survey that we envision at this time are to conduct a re-analysis of the trawl data to evaluate alternative assumptions about the underlying sampling distribution and other possibilities for stratifying the data to generate more precise confidence intervals on the abundance estimates. Ideally, we would also like to extend the survey into areas north of Vancouver Island and if this could be done in conjunction with an aerial survey this would extremely useful in terms of setting fishing harvest and providing the sardine industry with additional quota.



IV. Workshop Recommendations for Surveys to Enhance Stock Assessments

We see particular value in conducting an annual coastwide assessment of sardine population size into Canadian waters as far as the Alaska border. In some recent years sardine have been observed in the northern areas of British Columbia and we can't discount their migrations as far as southeast Alaska in strong el Nino years and as global warming conditions continue. I believe that there is also value in inter-calibrating some of the trawl surveys that are conducted off Columbia with chartered vessels such as the Frosti and also possibly with the Oscar Dyson. It should be possible to utilize the data from the Canadian trawl survey in the annual catch age analysis that supports the stock assessment.

We also see considerable promise for aerial surveys either with fixed wing visual or Lidar and possibly eventually via satellite. Our preliminary investigations into visual aerial surveys have not been promising due primarily to weather issues especially fog and wind. Nevertheless, we would welcome an opportunity to collaborate on a coastwide aerial survey of the entire sardine population. I think the general concensus is that there is more sardine biomass than appears to be indicated by the current assessment. However, the downward trajectory witnessed in the past few years suggests the need for caution and a more thoughtful evaluation of the various data sources.